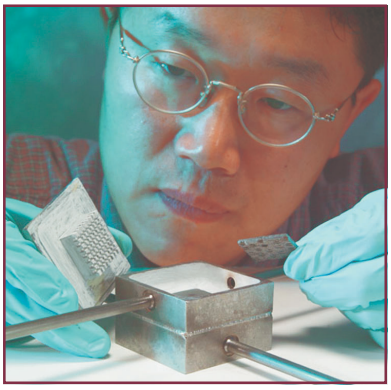
TuffCell Solid Oxide Fuel Cell and Diesel Fuel Reforming

A clean, affordable alternative to overnight idling

Argonne National Laboratory is developing a rugged solid oxide fuel cell that may soon provide a clean, affordable alternative to noisy, emissions-producing overnight idling of tractor-trailer trucks. Such fuel cells could be used in auxiliary power units (APUs) to provide electricity in tractor-trailers for operational needs, such as cargo refrigeration, and for operator comfort, such as cabin heating and cooling. Moreover, Argonne is developing a technology to reform diesel fuel for use in fuel cell applications. Thus, tractor-trailer trucks could soon be using diesel fuel not only for power to roll down the highway, but to create the hydrogen needed for clean, quiet, fuel-cell-powered APUs.

"TuffCell" Solid Oxide Fuel Cell



Argonne has developed a unique solid oxide fuel cell design that holds great promise for use in auxiliary power units. The key is the TuffCell's innovative metal-supported design, which provides easy fabrication and high mechanical strength.

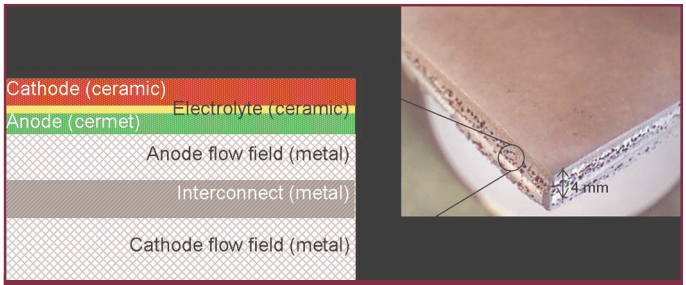
Fuel cells are like batteries. They cleanly convert the chemical energy of fuel into electricity without combustion and toxic emissions. Fuel cells are not new — they have been used for decades to power various things, from hospitals to space shuttles. What is new is Argonne's innovative metallic bipolar plate-supported design, which offers higher mechanical strength and lower cost than traditional solid oxide fuel cell designs. Developed by the Chemical Engineering Division's Fuel Cell Materials Group, TuffCell could be ready for commercialization in the next five years.

The innovation replaces costly, fragile ceramic cell support with a less-expensive, stronger, metallic bipolar plate. This new design also simplifies manufacturing, because traditional cells built with ceramic supports require up to four separate high-temperature processings, or sinterings, one for each layer. Argonne's method spreads the required layers of the oxide and metal materials — one on top of the other — and sinters them all in only one high-temperature processing step.

According to a study by Argonne mechanical engineer Frank Stodolsky, a single long-haul truck annually emits about 22 tons of carbon dioxide (a greenhouse gas); 390 pounds of carbon monoxide (a toxic pollutant); and 1,024 pounds of nitrogen oxides (which lead to smog formation), during idling alone (estimated at 1,830 hours per year). And there are nearly half a million such trucks on America's roads.

Auxiliary power units are beginning to replace idling for economic, efficiency and environmental reasons, as states are beginning to limit truck idling. TuffCell-powered units would offer higher power density and efficiency and would be more durable than current, diesel-engine-based units.

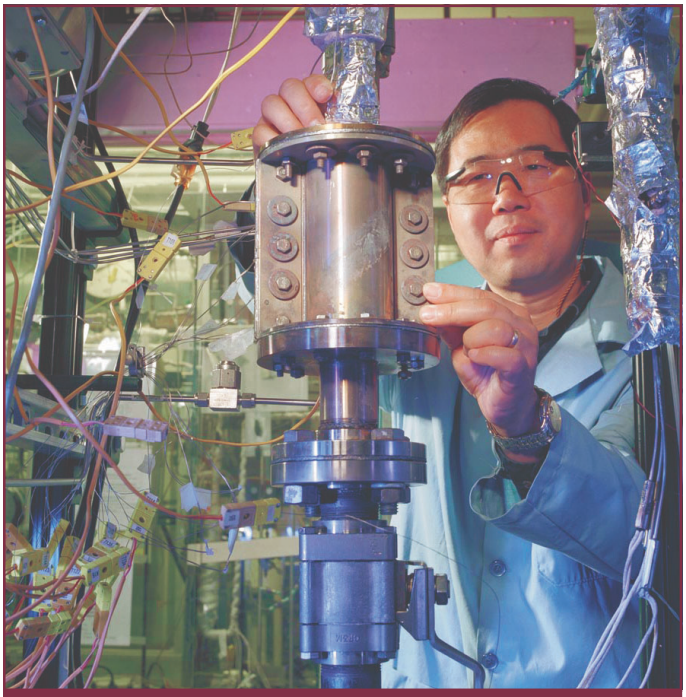
TuffCell research is funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, Hydrogen, Fuel Cells, & Infrastructure Technologies Program.



The TuffCell's bipolar-plate-supported design is one of the keys to its performance. The electrochemically active cell components (cathode, electrolyte, and anode) can be thin because they do not need to provide structural strength to the cell. Thinner layers mean less resistance, which leads to more power from the cell, and reduced materials cost.

Reforming Diesel Fuel to Power Solid Oxide Fuel Cells in Auxiliary Power Units

Until hydrogen is readily available, fuel reformers could reform diesel fuel into hydrogen to run Argonne's innovative TuffCell solid oxide fuel cell. TuffCell researchers are collaborating with other scientists in Argonne's Chemical Engineering Division to combine the fuel cell and fuel-reforming technologies for an auxiliary power unit.



Argonne has conducted extensive testing of the diesel reformer; the experiments are the first to show that an autothermal reformer can be operated without vaporizing diesel fuel.

Work on Argonne's diesel fuel reforming technology began when a team of scientists in the Chemical Engineering Division developed a new type of sulfur-resistant catalyst for use in fuel processors that efficiently converts a variety of hydrocarbon fuels — including methanol, natural gas, and gasoline — into a hydrogen-rich gas for use in auto-motive fuel cell systems. The catalyst was named one of the top 100 technological innovations of 2001 by R&D Magazine.

Getting the reformer to convert diesel fuel to hydrogen posed a new set of challenges, however, because diesel is difficult to vaporize. Complete vaporization requires high temperatures, which lead to pyrolysis and coking (carbonaceous deposits). Also, the conversion reaction to hydrogen from diesel requires three things — fuel, water/steam, and air — that must be present in specific proportions and must be mixed uniformly.

The key to solving these challenges is the feed nozzle that is used in the autothermal reactor. So, building on the success of the reformer catalyst and sponsored by the U.S. Department of Energy's Hydrogen, Fuel Cells & Infrastructure Technologies Program, researchers in Argonne's Nuclear Engineering Division have designed a new nozzle to overcome the limitations of the existing nozzle technology for diesel applications: namely, mixing and dispersion. Because the three feeds (water/steam, air, and fuel) cannot be premixed, the solution was to mix them in situ — right at the tip of the nozzle — to provide a uniform droplet size and dispersion across the catalyst bed.

Another team in the Chemical Engineering Division used the new nozzle and the Argonne catalyst (now commercially available from Süd Chemie, Inc., under a licensing agreement with Argonne) in a reactor setup that would allow Argonne to test the nozzle on an engineering scale. Extensive testing of the reactor generated data showing that diesel can be converted to hydrogen by using the new nozzle. These experiments were the first to demonstrate that an autothermal reformer can be operated without vaporizing diesel fuel and, therefore, without having to solve the kinds of problems that vaporization causes. The technology proved a success on three fronts: temperature and product distribution, product composition, and sustainability. Under typical operating conditions, reactor operation could be sustained for 5–6 hours, over each of several different days. The diesel reformer technology still requires considerable development before it is ready for commercialization, however. Long-term testing is needed, as are potentially improved catalyst formulations and processor designs. Researchers have obtained substantial industry input in the form of information about priorities and potential constraints, and the new nozzle technology and the data obtained thus far represent a big step forward.

For More Information

Under Argonne's Electrochemical Technology Program, Chemical Engineering Division, research is being conducted on fuel reformers (including a diesel fuel reformer), fuel cells, and hydrogen production and storage. The program also is home to the Fuel Cell Test Facility, established by the U.S. Department of Energy (DOE) to provide independent, standardized testing and evaluation for DOE and fuel cell developers and manufacturers. For more information, contact Romesh Kumar (630-252-4342, kumar@cmt.anl.gov) or visit http://www.cmt.anl.gov/science-technology/fuelcells/default.shtml